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Superfund, Hedonics, and the Scales of Environmental Justice

Douglas Noonan

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School of Public Policy
Georgia Institute of Technology
D. M. Smith Building
Room 107
685 Cherry Street
Atlanta. GA 30332 - 0345

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I. Introduction

The environmental justice (EJ) movement now occupies a prominent position in environmental policy. EJ is a core principle for thousands of grassroots environmental organizations, is the subject of a Presidential executive order and an office in the EPA, and recently served to frame how the nation viewed the tragic aftermath of Hurricane Katrina. This paper contributes to the research on environmental equity by (a) improving on traditional environmental justice research by incorporating results from economic analyses, and (b) presenting new evidence on the distributional equity of Superfund site locations at multiple scales.

Choosing the correct spatial scale for analysis continues to vex empirical EJ researchers. The modifiable areal unit problem (MAUP), often simplified as a matter of aggregation bias, has resisted solutions to date. The approach taken here turns to the well-established hedonic price literature to identify appropriate scales of analysis. Linking these two literatures holds the promise of practically addressing one of the larger obstacles to advancing empirical EJ claims. The utility of hedonic analyses for EJ research is demonstrated on a comprehensive, nationwide dataset of Superfund sites at four (nested) geographic scales. The results add to the EJ literature by performing multi-scale analyses nationally as well as focused on a specific site.

II. Literature Review on Scale in EJ

The basic research question posed by most EJ studies tends to resemble the following: "Are environmental conditions worse (are risks higher, is enforcement laxer, etc.) for certain types of people?" Operationalizing this question is no straightforward matter, however, and researchers have taken numerous different paths (see Mennis 2002 for additional discussion). Perhaps the most common approach involves multivariate regression frameworks where the dependent variable, some measure of environmental conditions in a geographic area, is predicted using demographic, political, and economic variables for that area. Such an approach, using geographic areas as the unit of observation, is made easy by the recent prevalence of demographic and environmental data aggregated to Census boundaries.[1] The researcher's choice of geographic area, however, opens the findings to critiques of arbitrariness or worse (Sui 1999, Bowen and Wells 2002, McMaster et al. 2002, Kurtz 2003, Glickman 2004).

Moreover, identifying the correct scale for analysis may not even be conceptually possible (Anderton et al. 1994). Consensus is lacking in the literature for a single, clear definition of the relevant unit of analysis. The boundaries around a group or community may not be clearly drawn (Kurtz 2003), and finding the relevant spatial scale for measuring group or community exposures may not be possible. Long before the advent of "environmental justice," Robinson (1950) pointed out the problems of "ecological fallacy." He showed the perils of presuming that correlations observed at the aggregate level were shared by disaggregated units. Poorer counties may tend to have more

[1] Disproportionate exposure for individual members of special populations may be observable with enough data, but such data rarely exist.

pollution, but this does not necessarily mean that poorer people tend to have more pollution.

Environmental justice research is inextricably linked to matters of space and scale. From the earliest studies, which found evidence of injustice at county (US GAO 1983) and zip code (United Church of Christ 1987) scales but later failed to find similar evidence at tract (Anderton et al. 1994, Davidson and Anderton 2000) scales, the critical role of scale became apparent.

Since then, numerous studies have explicitly acknowledged the importance of the choice of scale and sought to address it. Fotheringham and Wong (1991) note that, in a bivariate analysis, correlations should rise with the scale of aggregation, given stable covariance. Yet these effects become unpredictable for multivariate analyses.

Many authors in the recent EJ literature express intuitions and expectations about the effects of scale choice, providing a nice contrast with Fotheringham and Wong's (1991) pessimism about identifying predictable effects (especially for multivariate analyses). These expectations are summarized in Table 1A below. Maantay (2002) links the contradictory results in the literature to the choice of scale of analysis and traces this to the MAUP. Maantay seems to prefer smaller scales because they yield more accurate and reliable indicators of EJ, owing to the greater within-unit variance at larger scales. Glickman (2004) leans the other way, at least in his application. Cutter et al. (1996) claim that correlation coefficients should increase with scale, implying stronger evidence of injustice at large scales. Hockman and Morris (1998) state that smaller scales decrease the variability and thereby correlations, while larger scales inflate correlations too much. Ringquist (2005) sees unit of analysis largely as a matter of aggregation bias associated with larger scales, where injustice effects should appear stronger at larger scales. On the other hand, Dolinoy and Miranda (2004) express the intuition that smaller scales predict higher exposure concentrations. Others also advocate use of refined scales (e.g., Bowen 2001, McMaster et al. 2002). Because of the MAUP, Sui (1999) argues that results depend on both scale and zoning schemes used in defining areal units. He remarks that larger scales tend to yield fewer important variables, while zoning effects are less predictable.

Several studies provide empirical evidence of the effect of scale choice. Although Ringquist (2005) identifies scale choice as a major source of contention in the literature, his meta-analysis finds little evidence of systematic aggregation bias.

Others have conducted EJ studies at multiple scales. Using multiple scales for the same scope (in space and time), and the same statistical methods, allows the sensitivity of results to be directly measured.[2] For examples of this research, see Anderton et al. (1994), Bowen et al. (1995), Cutter et al. (1996), Sui (1999), Taquino et al. (2002), and Dolinoy and Miranda (2004). Their findings are also summarized in Table 1B below. In total, while the conventional wisdom may be that effects get stronger as scale increases (Table 1A), the empirical evidence on the matter is quite mixed (Table 1B).

[2] The Ringquist (2005) meta-analysis studies how results vary within *and* across studies as scale changes, as opposed to just how results vary within studies as scale changes.

Table 1A: EFFECTS OF SCALE, IDENTIFIED FROM INTUITION OR THEORY

Author	**Effect as Scale Increases**	**Comment**
Fotheringham & Wong (1991)	Correlations ↑	Bivariate only, with stable covariance
Fotheringham & Wong (1991)	unknown	Multivariate
Cutter et al. (1996)	Correlations ↑	
Hockman and Morris (1998)	Correlations ↑	
Sui (1999)	Correlations ↓	Due to scale effects
Sui (1999)	unknown	Due to zoning effects
Maantay (2002)	Reliability ↓	
Maantay (2002)	Accuracy ↓	
Dolinoy and Miranda (2004)	Exposures ↓	
Ringquist (2005)	Correlations ↑	Aggregation bias

Table 1B: EFFECTS OF SCALE, IDENTIFIED FROM EMPIRICAL ANALYSIS

Author	**Effect as Scale Increases**	**Comment**
Ringquist (2005)	Mixed for race, no effect for income, effects ↓ for poverty	Meta-analysis of EJ studies
Anderton et al. (1994)	Correlations ↑	Multi-scale study (only tract vs. tract-plus-adjacent-tracts)
Glickman (1994)	Race correlations ↑, income correlations ↓	Multi-scale study
Cutter et al. (1996)	Correlations ↑	Multi-scale study
Sui (1999)	Race correlations ↑, income correlations ↓	Multi-scale study
Sheppard et al. (2002)	Income correlations ↑	Multi-scale study
Taquino et al. (2002)	Income correlations ↑, no effect for race	Multi-scale study
Dolinoy and Miranda (2004)	Mixed for income, race correlations ↓	Multi-scale study
Glickman (2004)	Race correlations ↑, income correlations ↑	Multi-scale study

Most EJ studies, however, are conducted at a single spatial scale. Often, this choice of spatial scale is either driven by data availability or not explicitly justified by the authors. In some cases, EJ researchers simply assert what scale is appropriate. Scales range from Census blocks (e.g., Chakraborty et al. 1999) to counties (e.g., Earnhart 2004) and many scales in between (e.g., Pollock and Vittas 1995, Been and Gupta 1997, Taquino et al. 2002, Yandle and Burton 1996, Anderton et al. 1994, Hockman and Morris 1998, Banzhaf and Walsh 2004).

While studies that employ environmental modeling to spatially portray environmental conditions in greater detail are growing more popular in the EJ literature, this paper proposes a different approach. Rather than rely on sophisticated models of environmental transport or plumes, market data can provide alternative measures of the spatial extent of environmental hazards. Property markets reflect the impact of environmental disamenities via sales prices. Such market representations of impacts may not match perfectly with more strictly geophysical environmental models. Yet they should capture at least the risks as they are perceived by residents (i.e., those possibly suffering from the injustice) rather than risks as estimated in an expert's assessment. Moreover, price effects can capture the full impact of a particular disamenity, including aesthetics or congestion or other attributes not included in a strictly geophysical model. Gayer et al. (2000) find that a housing market reflects Superfund sites risks quite accurately. Letting property markets inform researchers as to the spatial extent of impact of environmental hazards offers an objective guide to EJ researchers in choosing the spatial scale for their analysis.

III. Literature Review on Hedonics and NPL

Hedonic price method studies can help address one of the more vexing problems in EJ research: the choice of spatial scale. For many environmental hazards, numerous hedonic price studies have revealed considerable information about the spatial extent and scale of impact. Hedonics employs statistical analyses to identify how much variation in sales prices are attributable to different features of the property (e.g., lot size, number of rooms, distance to an amenity). Price effects have been measured for environmental disamenities commonly discussed in the EJ literature, such as landfills (e.g., Hite 2001, Hite et al. 2001, Nelson et al. 1992), TSDFs / RCRA sites (Thayer et al. 1992, Industrial Economics 2000), and air quality (Smith and Huang 1995; Boyle et al. 2001, Smith, et al. 2004). This paper explores another area popular in both EJ and hedonic literatures: Superfund National Priorities List (NPL) sites.

Of interest here are studies that identify when the price effects of proximity to NPL (or other hazardous) sites fade to zero. Table 2 reviews 14 studies that use the hedonic price method to measure the effect on property prices of distance to an NPL or other hazardous waste site.[3] Table 2 reports the hazard(s) studied and, for NPL sites only, environmental media through which the risks are transmitted. The EPA tracks the contaminated media for NPL sites, whether it is air (A), water (W), soil (S), other (O), or some combination.[4] Table 2 also reports the maximum distance at which the site(s) affects property values,

[3] One of the early economic studies found that a hazardous waste site has to be located 10 miles away for a majority of suburban residents to accept the waste site without compensation (Smith and Desvousges 1986). This study is omitted here, because it does not use a hedonic methodology.
[4] The "air" category includes only the air contaminated media type. The "water" category consists of contaminated groundwater, leachate, liquid, and surface water media. The "soil" category is composed of soil, debris, sediment, sludge, solid waste, subsurface soil, and surface soil. The "other" category contains other and residuals contaminated media. The contamination data for each site comes from the EPA's CERCLIS (EPA 2003). Many sites have multiple contamination types.

and whether the distance is derived or assumed.[5] Most effects were found to dissipate within one to three miles; all results find price effects are indistinct after six miles.

TABLE 2: SUMMARY OF NPL SPATIAL ECONOMIC IMPACT STUDIES

Study	**Hazard**	**NPL media type**	**Max. distance of effect**
Michaels and Smith, 1990	Eleven NPL and non-NPL sites in suburban Boston	Many sites/media	No discussion
Kohlhase, 1991	Pooled NPL sites in Harris county, TX	Many sites/media	6.19 miles
Kohlhase, 1991	Brio Refining Inc	A, W, S, O	2.61 miles
Kohlhase, 1991	Crystal chemical Co	W, S	2.94 miles
Kohlhase, 1991	Geneva Industries	W, S, O	1.86 miles
Kohlhase, 1991	Harris-Farley	A, W, S	4.87 miles
Kohlhase, 1991	Sol-Lynn Industrial transformers	W, S, O	3.92 miles
Kohlhase, 1991	South Cavalcade St	W, S	4.76 miles
Kiel, 1995	Industriplex and W&G Well, Woburn, MA	*Industriplex*: A, W, S *W&G Well*: W, S, O	No discussion
Dale et al., 1999	RSR Smelter in Dallas	W, S, O	Slower rebound within 2 miles of the site compared to other areas.
Gayer et al., 2000	Seven NPL sites & non-NPL sites in Grand Rapids, MI	Many sites	No discussion
Kiel and Zabel, 2001	Industriplex and W&G Well, Woburn, MA	*Industriplex*: A, W, S *W&G Well*: W, S, O	Assumed to be zero beyond 3 miles from the site
McClusky and Rausser, 2003	RSR Smelter in Dallas	W, S, O	Price premium for distance flattens out after 2.6 miles
Deaton and Hoehn, 2004	Barrels, Inc., and Motor Wheel, Lancing, MI	*Barrels, Inc*: Not available *Motor Wheel*: W, S	No assumptions on maximum distance effect
Chattopadhyay et al., 2005	Waukegan Harbor, IL	S, W	Distance effect is assumed to vanish after 5 miles
Kiel and Williams, 2005	57 NPL sites in 20 counties	Many sites/media	Assumed to be 3 miles
Hite et al., 2001	Four landfills, Franklin County, OH	Not an NPL site	Assumed to be 3.25 miles
Nelson et al., 1992	Landfill (non-hazardous) in Minneapolis	Not an NPL site	2.5 miles
Smolen et al., 1992	"Envirosafe Landfill", Toledo, OH	Not an NPL site	No effect of waste site on prices for "greater than 5.75 m" range.
Thayer et al., 1992	Waste (hazardous & non-hazardous) sites in Baltimore	Not an NPL site	Gradient shifts after 1 mile and 4 miles in linear specification and after 5 miles in semi-log
Ihlanfeldt and Taylor, 2004	Hazardous waste sites in Atlanta	Not an NPL site	Assumed a threshold of 2 mile radius from the sites

[5] Although many of the studies reviewed are concerned with the timing of information flows and consumer responses, for purposes of comparability, only distance effects for periods when the presence of a site is clearly recognized are reported.

See Table A in the Appendix for additional details about these studies. Table A also reports estimated price gradients for those that estimated them. Most gradients estimated show property values rising between 1% and 6% per mile of distance.

IV. Data and Methods

To demonstrate the usefulness of using an economic approach to defining the scale of analysis, this paper conducts numerous conventional EJ studies for NPL sites. The hypothesis is that evidence of injustice is sensitive to the choice of scale. In addition, this paper identifies systematic patterns in evidence of injustice as scale and the characteristics of the hazard both vary. The second hypothesis tested is whether hazards typically associated with larger spatial impacts tend to exhibit unjust siting at different scales than more spatially confined hazards. In other words, the analysis tests whether evidence of injustice exists when the size of the footprint of a site corresponds to the scale of analysis, as revealed by the hedonics literature.

A conventional empirical EJ model is developed here. This lends comparability between our findings and those prevalent in the EJ literature. This analysis seeks to identify the sensitivity of commonly reported EJ evidence to the choice of scale and then to demonstrate how that sensitivity relates to the spatial extent of impacts as measured through property markets.

A logit model predicts the presence of a site using several covariates standard in the EJ literature. The dependent variable equals 1 if there is at least one site listed on the NPL as of the year 2002 in the areal unit, and zero otherwise. Similar approaches can be found in Anderton et al. (1994), Been (1995), and Cutter et al. (1996), among others. The control variable definitions and their summary statistics are in Table 3. The variables of interest capture three forms of injustice: percent black, percent Hispanic, and median household income. Environmental racism or inequity for the poor can be identified if the coefficients for these variables are found to be significant and positive or negative, respectively. All demographic variables are from the 2000 U.S. Census and include the entire United States.

TABLE 3: DESCRIPTIVE STATISTICS

	County		Zip Code		Tract		Block Group	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
NPL	0.2118	0.4086	0.0278	0.1643	0.0220	0.1468	0.0072	0.0845
MSA	0.3759	0.4844	0.5153	0.4998	0.8125	0.3903	0.7975	0.4019
Density	0.0001	0.0008	0.0004	0.0015	0.0020	0.0046	0.0023	0.0051
Population	105.5893	377.2830	6.7066	12.0431	4.3068	2.1368	1.3514	0.8978
Urbanicity	0.4273	0.3227	0.3378	0.4248	0.7768	0.3740	0.7737	0.3930
Manufacturing	0.0706	0.0428	0.0687	0.0593	0.0652	0.0416	0.0667	0.0467
Unemployment	0.0273	0.0123	0.0259	0.0293	0.0300	0.0278	0.0295	0.0307
Housing value	88.095	55.366	87.371	90.055	134.034	110.776	130.527	113.551
Education	0.5057	0.0748	0.5294	0.1309	0.5186	0.1303	0.5213	0.1408
Black	0.0871	0.1429	0.0730	0.1636	0.1358	0.2357	0.1316	0.2440
Hispanic	0.0884	0.1917	0.0646	0.1521	0.1260	0.2122	0.1229	0.2170
Income	35.0828	9.6892	33.6503	21.6335	43.6071	21.0979	44.0603	22.9905

Variable descriptions:
NPL – Dummy variable taking a value of 1 if areal unit contains at least one NPL site
MSA – Dummy variable taking a value of 1 if areal unit is in or abuts a metropolitan statistical area
Density – Population density of areal unit, measured as total population divided by area (in m^2)
Population – Total population (in 1000s) of areal unit
Urbanicity – Share of total population that is classified as "urban population" in areal unit
Manufacturing – Share of employed population working in manufacturing jobs in areal unit
Unemployment – Unemployment rate in areal unit
Education – Share of total population in areal unit who have graduated high school
Housing Value – Median housing value (in $1000s) in areal unit
Black – Share of population identifying self as black or African American or Negro as primary racial classification in areal unit
Hispanic – Share of population identifying self as Hispanic or Latino in areal unit, not mutually exclusive with Black
Income – Median household income (in $1000s) in areal unit

Identical analyses were performed at each of four different geographic scales: county, zip code, tract, and block group. Table 3 below shows descriptive statistics for the variables across different scales. All models include state-level fixed and random effects. The logit models were also estimated for subsamples of the NPL sites based on the media of their contamination. Dummy variables for four categories of contaminant media are constructed as air, water, soil, and other. Separate logit models for each media type can be interpreted as estimating the location-specific demographic characteristics for each type of NPL site. In this way, unjust siting conditions for different types of sites can be observed at different spatial scales.

V. Results

The results of the full sample logit models are summarized in Table 4 below. The results are broadly consistent with the existing EJ literature.

Several of the non-justice variables show evidence of scale induced variability. The variable for education is most affected by scale choice. Highly educated zip codes and tracts are less likely to have NPL sites, while highly educated block groups are more likely. The results for unemployment are also scale dependent – positive and significant at the county level, negative and marginally significant at the tract level. Property values exhibit a weak relationship to scale choice. Higher housing values are associated with greater likelihood of NPL siting at the tract scale, but the effect is not significantly different from zero at other scales.

Table 4: LOGIT REGRESSION RESULTS FOR NPL SITES NATIONWIDE

	County	Zip Code	Tract	Block Group
	Coef.	Coef.	Coef.	Coef.
MSA	0.4673***	0.3718***	0.3143***	0.4545***
	(3.63)	(4.53)	(4.13)	(6.34)
Density	-320.5872***	-552.9978***	-1038.214***	-1299.582***
	(3.00)	(11.41)	(20.33)	(23.59)
Population	0.0004*	0.0288***	0.0980***	0.2142***
	(1.78)	(12.90)	(8.35)	(11.20)
Urbanicity	2.6354***	1.3947***	0.4402***	0.4946***
	(11.01)	(13.49)	(4.98)	(6.32)
Manufacturing	3.9931**	2.7597***	3.5201***	2.5736***
	(2.36)	(5.45)	(4.98)	(4.42)
Unemployment	14.5944**	0.2202	-2.3665*	0.5971
	(2.21)	(0.17)	(1.78)	(0.76)
Housing value	-0.0014	-0.0003	0.0009*	0.0004
	(0.69)	(0.47)	(1.69)	(0.87)
Education	1.399	-1.2679***	-2.101***	0.4545***
	(1.00)	(3.56)	(5.52)	(6.34)
Black	1.0535*	0.7094***	0.6003***	0.5699***
	(1.80)	(3.27)	(3.21)	(3.50)
Hispanic	-0.8111	0.2179	0.5589**	0.4275*
	(1.03)	(0.75)	(2.11)	(1.83)
Income	0.0187*	0.0015	-0.0096***	-0.0075***
	(1.65)	(0.58)	(3.68)	(3.51)
constant	-4.8874***	-4.7943***	-3.9831***	-5.1016***
	(5.53)	(13.90)	(11.45)	(16.17)
N	3376	40844	66000	209899
LR $\chi^2(61)$	518.42	1292.38	1017.81	1341.32
Prob > χ^2	0	0	0	0

Absolute value of z statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

NPL sites are not distributed randomly with respect to demographics. Areas with greater proportions of blacks are more likely to have an NPL site, at all scales considered here. Greater proportions of Hispanics are also positively associated with NPL site locations, but only at the smaller scales. Perhaps most interestingly, poorer areas are more likely to have NPL sites when those areas are small (i.e., tracts or block groups), but richer areas are more likely to have NPL sites when the scale is large. Overall, across the different scales of analysis, the evidence of justice is mixed. For blacks, the evidence points to consistent injustice. For Hispanics, however, the evidence points to injustice only at some scales. And, for the poor, the evidence switches across scales, demonstrating both justice and reverse injustice depending on the scale chosen.

The sensitivity of some of the evidence to spatial scale is particularly interesting in light of the conclusions of previous research (as summarized in Tables 1A and 1B). Most authors expect that scale matters. For NPL sites in the U.S., however, the pattern in Table 4 contradicts the conventional wisdom among many geographers and others in the EJ field that injustice is more easily observed at large scales because demographic variance increases with disaggregation.[6] Authors like Cutter et al. (1996) and Ringquist (2005) expect EJ effects to be more pronounced at large scales. Table 4 indicates the strongest evidence of injustice at the block group and tract scales, weakening and sometimes even reversing at the larger scales.

The sensitivity of the results to scale highlights the importance of the researcher's choice of scale. The hedonic literature on NPL and hazardous waste can guide the selection of scale, however. Most studies identify that price effects of proximity to hazardous waste sites dissipate within 2-5 miles. Some studies find no price effects or even positive price effects, however, so this estimate does contain considerable noise. Nonetheless, if the

[6] In our sample, notice that the variance of Black rises as the scale shrinks, but Hispanic and Income exhibit nonmonotonic variance changes. Moreover, significant effects tend to disappear at aggregated scales. This contrasts with a common view that variance tends to increase with disaggregation and that significant correlations then disappear at disaggregated scales.

common figure of three miles is used (Kiel and Zabel 2001, Kiel and Williams 2005),[7] this suggests the choice of zip code as the proper scale. This follows Glickman (2004) and Ringquist's (2005) recommendation to somehow match researchers' definitions of community to the actual area of environmental impact. In the sample, the median area of counties, zip codes, tracts, and block groups are 598.5, 22.8, 2.0, and 0.5 square miles, respectively. The footprint of a site likely extends well beyond the boundaries of the block group that it sits in, whereas the county may contain considerable area that is completely unaffected by the site. Tracts are also likely to be too small to capture the extent of the NPL site. Using this approach, the zip code scale suggested by the hedonic literature exhibits some evidence of injustice.

Extending this approach further, Table 5 provides a summary of additional estimations of logit models that predict the presence of NPL sites by media. Separate estimations are performed for air, for water, for soil, and for other sites. The results are given for the race and income variables only, while the control variables are omitted from the table for brevity.

Table 5 reveals several patterns. For air-polluting NPL sites, injustice appears with respect to race at small scales only. The sign on the effect of Hispanic changes and becomes significant at the county scale. In addition, income is only significant at the county level. At this largest scale, wealthier and less Hispanic counties are more likely to have air-related NPL sites. For water-related sites, injustice with respect to blacks appears below the county scale, with respect to the poor below the zip code scale, and

[7] Cameron et al (2005) use a 7.5-mile radius, beyond which they assert price effects are unlikely.

with respect to Hispanics at the tract level only. Soil-related sites are more likely to be found in more black areas (when the area is smaller than county) and in poorer and more Hispanic areas (when the area is smaller than zip codes). The effect of Hispanics, however, reverses at the county scale – where Hispanics are less likely to be in counties with soil-polluting NPL sites. For "Other" sites, Black is positively associated with the probability of hosting an NPL site at any scale. While injustice appears for Hispanics at scales below the county scale, the results for income again mixed.

TABLE 5: SUMMARY OF EJ RESULTS ACROSS SCALES, MEDIA

Sample	Variable	County	Zip Code	Tract	Block Group
Full	Black	1.054*	0.709***	0.600***	0.570***
	Hispanic	-0.811	0.218	0.559**	0.427*
	Income	0.019*	0.002	-0.010***	-0.008***
Air	Black	0.759	0.172	0.849**	0.692**
	Hispanic	-2.818*	0.749	1.314***	0.872*
	Income	0.032**	0.006	-0.005	-0.005
Water	Black	0.882	0.628***	0.665***	0.627***
	Hispanic	-1.399	0.231	0.512*	0.367
	Income	0.013	0.002	-0.011***	-0.007***
Soil	Black	0.719	0.692***	0.666***	0.670***
	Hispanic	-1.867**	0.193	0.577**	0.451*
	Income	0.011	0.001	-0.011***	-0.006***
Other	Black	2.051**	0.797**	0.967***	0.795***
	Hispanic	-0.214	1.085**	1.340**	1.029**
	Income	0.027*	0.003	-0.009*	-0.001
* significant at 10%; ** significant at 5%; *** significant at 1%					

Sites with different contaminants may be expected to have varying spatial impacts. The hedonic literature suggests that the effects of proximity do indeed vary substantially across sites, although explaining this variation remains a challenge. If sites with air contaminants have broader impacts, and those with soil contaminants have a more confined impact, how evidence of injustice varies across contaminant types can give at least a crude indication of the pattern of injustice for NPL sites nationwide. For air contaminant sites, the evidence rejects the injustice hypothesis for blacks, Hispanics, and the poor, especially at the county scale. If the larger scale is the most appropriate for these sites, the evidence points to disproportionately higher exposure for counties with more income and fewer Hispanics. For soil contaminant sites, on the other hand, the evidence supports the injustice hypothesis for blacks, Hispanics, and the poor, especially at the tract and block-group scales. If these smaller scales are most appropriate for these sites, it appears that minorities and the poor are disproportionately exposed to soil contaminant NPL sites. For water contaminant sites, the evidence is much more mixed. The significance and even the sign of the effects for Hispanic and Income depend heavily on the scale chosen. Overall, the evidence of injustice for particular types of NPL sites is roughly comparable to the evidence of injustice across all NPL sites. Logit analyses at small scales support the injustice hypothesis, whereas these effects vanish and reverse at larger scales.

VI. Discussion

Evidence of environmental injustice varies substantially across geographic scales. Table 4 depicts this inconsistency for NPL sites nationwide. While theories of environmental justice provide limited guidance on the proper geographic scale, data limitations make an ideal solution unlikely, especially using the geography developed by the Census.

Hedonic analyses of property markets may help researchers address this problem by identifying appropriate geographic bounds. One approach follows a rough consensus in the empirical literature that NPL and other hazardous sites' impacts typically extend 2-5 miles away from the site. Their impact zone appears larger than tracts or block groups, yet smaller than counties. The analysis in Section IV uses this estimate to suggest that zip codes may be the appropriate scale to conduct a conventional EJ study for NPL or hazardous facilities. Furthermore, if the spatial impact zone of an NPL site is related to the media that it contaminates, we might reasonably use different scales for different types of sites in conventional EJ analyses. The analysis, summarized in Table 5, shows that the evidence of environmental inequity differs only somewhat across media types.

In order to demonstrate how one can use results of hedonic studies in EJ analysis, we analyze environmental equity around the South Cavalcade St NPL site in Harris County, TX using results of Kohlhase (1991). Using a buffer of 4.76 miles around the NPL site[8] allows for a test of the difference in means of EJ variables (i.e., percent black, percent Hispanic, and median income) inside and outside of this buffer. This analysis is conducted at both Census tract and Census block group scales within Harris County. Evidence at both scales for all three variables suggests environmental injustice around South Cavalcade NPL site. For instance, the mean percent black in block groups or tracts within the buffer is 11.7% or 12.5%, respectively, greater than elsewhere in the county. Median household incomes are $21,000 lower inside the buffer than outside. Using a logit model, the likelihood of a block group or tract being inside the buffer is positively associated with percent minority and negatively associated with income. The results for the difference in means and for the logit analysis all point to significant evidence of

[8] 4.76 miles is the distance threshold for that NPL site found by Kohlhase (1991).

environmental injustice (except for percent black at tract level). The results are presented in Table 6 below.

TABLE 6: SOUTH CAVALCADE ENVIRONMENTAL INJUSTICE RESULTS

	Difference in Means[a]		**Logit Analysis**	
	Block Group	**Tract**	**Block Group**	**Tract**
Percent Black	11.7 (6.6)	12.5 (4.3)	1.84 (4.27)	1.35 (1.58)
Percent Hispanic	22.0 (12.8)	20.1 (7.4)	2.98 (6.76)	2.6 (3.0)
Median Income ($)	21843 (12.5)	21088 (7.7)	-0.00005 (-5.75)	-0.00007 (-3.7)

[a] Positive difference indicates injustice.
Numbers in parenthesis represent t- or z-statistics as applicable

VII. Conclusion

This paper has reviewed the intractability and confusion arising due to the MAUP in the context of environmental justice. Political and legal imperatives will continue to demand EJ analyses despite these challenges. This paper proposes that an economic approach, the hedonic price method, offers useful guidance to a policymaker or administrator tasked with conducting an original EJ analysis. The hedonic literature for all manner of disamenities can be used to inform the choice of scale and geographic scope in environmental justice studies. It adds to the validity of the researchers' scale choice. Such an approach might inform the choice of the zip code scale for an analysis such as in Table 4. And, for EJ studies of a particular hazardous site for which results of a hedonic analysis are available, these findings can instruct the design of appropriate tests of injustice. This approach is demonstrated in Table 6.

A second way to use hedonic methods to improve empirical EJ analyses is examined in Section V. Here, results from an hedonic analysis of the South Cavalcade NPL site in Harris County, TX help identify which residents are in the impact zone of the hazard and those that are not. At least with respect to this sit, the evidence strongly supports the existence of environmental inequities.

A more ambitious approach is also suggested by this analysis. Given the technological advances in statistical and GIS software and the increasing availability of demographic data in many cities, hedonic estimates are increasingly easier to perform. To properly calibrate an environmental justice study, thereby reducing potential claims of bias, a policy analyst could estimate a simple hedonic regression to determine the extent of the spillover effects of a disamenity on property values. This information could then be used to inform an investigation of the extent of environmental injustice.

Public agencies are often faced with the difficult task of conducting objective analyses of complex problems, and environmental justice is surely no exception. Considerable heated debate surrounds the use of empirical evidence on this topic. Up to this point, surprisingly little practical guidance has been offered to agency officials, planners, or policy advocates, seeking to produce objective, valid measures of environmental justice. This paper marks a step in this direction. It suggests that the mountain of hedonic research produced by urban and real estate economists can be used to craft more robust EJ studies. The hedonic approach lets behavior in housing markets indicate the scale and scope of a hazardous facility's impact. Armed with this evidence, the EJ researcher's task is greatly simplified in assessing environmental equity.

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Appendix

TABLE A: EXPANDED SUMMARY OF NPL SPATIAL ECONOMIC IMPACT STUDIES

Study	**Sample**	**Method**	**Hazard**	**NPL media type***	**Gradient**	**Max. distance of effect**
Michaels and Smith, 1990	Home sales in suburban Boston, 1977-1981	First-stage semi-log hedonic	Eleven NPL and non-NPL sites	Many sites	0.3% per mile to closest site	No discussion
Kohlhase, 1991	Appraisers' individual housing sales data (1976, 1980, and 1985) for Harris County, TX from	First stage hedonic regressions	Pooled NPL sites in Harris County, TX	Many sites	$2360 per mile for an average home located at the average distance	6.19 miles
			Brio Refining Inc	A, W, S, O		2.61 miles
			Crystal Chemical	W, S		2.94 miles
			Geneva Industries	W, S, O		1.86 miles
			Harris-Farley	A, W, S		4.87 miles
			Sol-Lynn Industrial transformers	W, S, O		3.92 miles
			South Cavalcade St	W, S		4.76 miles
Smolen, Moore, and Conway, 1992	Real estate sale transactions from court house transaction data for greater Toledo, OH	First stage linear hedonic regressions	Envirosafe Landfill, Toledo, OH	Not an NPL site	$12,000 per mile for 0-2.6 m and 2.6-5.75 m ranges. -$1800 for "more than 5.75 m" range	Similar effects for 0-2.6 and 2.6-5.75 mile ranges and no effect for "greater than 5.75 m" range
Thayer et al., 1992	Home sale price data of owner-occupied single-family dwellings (1985-1986) for Baltimore	First stage linear, semi-log, and log-linear hedonic regressions	Waste (hazardous & non-hazardous) sites in Baltimore	Not an NPL site	Linear: $ 1348 Semi-log: 1.6% Elasticity: 1.1%	Gradient shifts after 1 and 4 miles in linear model and after 5 miles in semi-log model
Dale et al., 1999	Home sale price of owner-occupied single family dwellings (1979-1995), Dallas	First stage linear hedonic regressions	RSR Corporation, Dallas	W, S, O	Approximately 2% before site clean up	Slower rebound within 2 miles of the site compared to other areas, post-clean up
Kiel and Zabel, 2001	Single-family home sales in Woburn, MA between 1975 and 1992	Semi-log first stage hedonic regressions	Industriplex and W&G Well, Woburn, MA	*Industriplex*: A, W, S *W&G Well*: W, S, O	WTP - 11.6% of house price for a house located 0.5 miles from the site	Assumed to be zero beyond 3 miles from the site, based on data

Study	**Sample**	**Method**	**Hazard**	**NPL media type***	**Gradient**	**Max. distance of effect**
Ihlanfeldt and Taylor, 2004	Industrial and commercial property sales price data for Fulton County, GA	First stage hedonic regressions with inverse of distance as distance variable	Hazardous waste sites in Atlanta, GA	Not an NPL site	Average office building: 36% increase (for moving from 0.5 to 2 miles) Average industrial building: 3%	Based on their data, assumed a threshold of 2 mile radius from the sites beyond which impact of hazardous waste sites is negligible
McClusky and Rausser, 2003	Sales price data of single-family detached homes sold during 1979-1995 in Dallas County, TX	Two stage hedonic regression with spline function for distance in first stage	RSR Smelter in Dallas	W, S, O	0.88% pre cleanup 3.22% post cleanup	Price premium for distance flattens out after a distance of 2.6 miles
Kiel, 1995	Assessor Sales Data, 1975-1992 for Woburn, MA	First stage log-linear hedonic regressions	Industriplex and W&G Well, Woburn, MA	*Industriplex*: A, W, S *W&G Well*: W, S, O	2.5 % during the announcement to 5.1% during clean up period	NA
Chattopadhyay et al., 2005	Assessor property sales data for Lake County, IL during 1996-2001	First stage log-linear model	Waukegan Harbor, IL	S, W	11% for houses in the city with NPL sites	Distance effect is assumed to vanish after 5 miles
Nelson et al., 1992	Assessor data on single-family homes in 1980 in Minneapolis	First stage linear hedonic regression	Landfill (non-hazardous) in Minneapolis	Not an NPL site	12% at the boundary of landfill and 6% at 1 mile away	2.5 miles
Gayer et al., 2000	Housing sales data for Grand Rapids Area, MI during 1998-1993	First stage semi-log hedonic regression	Seven superfund sites and some non-Superfund sites in Grand Rapids	Many sites	1.4% without NPL site variables; 1.2% otherwise	No discussion
Hite et al., 2001	County records of sales price transactions in Franklin County, OH for 1990	First stage hedonics with squared distance for each landfill	Four landfills in Franklin County, OH	Not an NPL site	Predicted rent at mean distance from landfill sites: $5000 to $9000	Assumed to be 3.25 miles
Deaton and Hoehn, 2004	Assessor's office data on residential housing sales, City of Lansing, MI (1992-2000)	First stage log-linear hedonic regression	Barrels, Inc., and Motor Wheel in Lansing, MI	*Barrels, Inc*: NA *Motor Wheel*: W, S	3.2% elasticity without industrial proximity variable	No assumptions on maximum distance effect
Kiel and Williams, 2005	Real estate transactions at housing unit level for 20 counties (1970-1990)	First stage log-linear hedonic regressions for 57 NPL sites	57 NPL sites in 20 counties	Many sites	0.94% to 92% with a mean of 16% for sites showing positive distance coefficient	Assumed to be 3 miles

* A – Air, W – Water, S- Soil, O – Other; NA – Not available